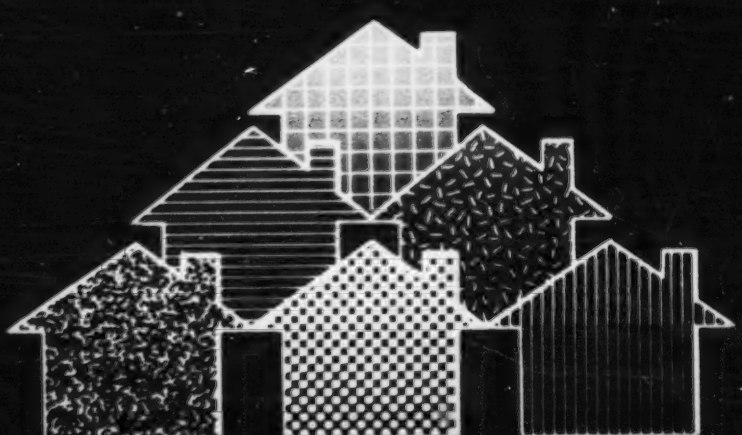
The development of a knowledge base relating to indoor use of caulks, sealants and weatherstrip products

Volume 1

An overview of the study



Canada

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EXECUTIVE SUMMARY

A study has been conducted for the Home Energy Program of Energy, Mines and Resources Canada (HEP/EMR) by Saskatchewan Research Council (SRC). The study was conducted in the context of residential air sealing, in which houses are made more energy-efficient by the use of caulks, sealants and weatherstrips.

The general objectives were to develop procedures that would:

a) Maximize the effectiveness and durability of seraling work, and
b) Minimize health hazards to house occupants and sealing workers.

To accomplish these objectives, a series of methods has been developed for testing the performance of caulks, sealants and weatherstrip products. These methods have been assessed by applying them to a representative range of products. Based on the results of these tests, a draft Test Standard and Performance Standard have been prepared for caulks and sealants, and also for weatherstrip products. Two draft Workmanship Standards have been prepared: one dealing with the installation of caulks and sealants; the other with the installation of weatherstrip products.

A method has been developed for measuring the rate of emission of toxic volatiles from caulks and sealants, and a mathematical procedure has been developed for analysing the test data so as to give a safety rating to caulks and sealants.

The study was started at the end of November, 1985. The final deliverables, including this volume, were submitted in December 1987. The course of the study was guided by two Advisory Committees.

The findings of the study are presented in five volumes. This is the first volume in the series and consists of an overview of the entire study. The detailed objectives and the general history of the study are presented. A guide to the various technical volumes is given and the main findings and highlights of the study are identified.

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Mr. G. Wichenko of Appin Associates
Mr. T. Woods of Can-Am Air Leakage Control Corp.
Mr. R. Zaborniak of Canada Mortgage & Housing Corporation.

Advisory Committee on Weatherstrip:

Mr. R. Coomber of Unique Sash Balance Co.
Mr. K. Kennard of NECA Contractors
Mr. E. Morin of Unique Sash Balance Co.
Mr. M. Schotsch of Schlegel Canada Inc.
Mr. C. Warner of Can-Am Air Leakage Control Corp.
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Mr. T. Woods of Can-Am Air Leakage Control Corp.
Mr. D. Young of Canadian General Standards Board
Mr. R. Zaborniak of Canada Mortgage & Housing Corporation.

1. INTRODUCTION

This is an overview of a study conducted for the Home Energy Program (HEP/EMR) of Energy, Mines and Resources Canada by the Saskatchewan Research Council (SRC). The study was concerned with the practice of increasing the energy-efficiency of houses by using caulks, sealants and weatherstrip products to reduce air leakage heat losses. The general objectives were to develop procedures that would:

a) maximize the effectiveness and durability of sealing work, and
b) minimize health hazards to house occupants and sealing workers.

The need for such procedures was first recognised during the preparation of the manual "Air Sealing Homes for Energy Conservation" (1), published by the Buildings & Energy Technology Transfer Program of Energy, Mines and Resources Canada (BETT/EMR). This manual dealt predominantly with the use of caulks, sealants and weatherstrip products. When it came to specifying these it was realised that very little was known about them. Up to that time, caulks and sealants were marketed mainly for outdoor applications. How would they work indoors on surfaces of various types with various conditions of deterioration and dampness? Would they give a durable seal? Would their volatile components create a hazard for house occupants? There were no ready answers to these and similar questions. Weatherstrip products had been popular with the do-it-yourself market for many years, but in the context of energy conservation these products had to be given a closer scrutiny. How did one distinguish between a good product and a bad? How effective were they in reducing air leakage? How durable were they? Once again, there were no ready answers. The specifications in the manual were therefore based partly on limited information and partly on the best judgements possible at that time. The exercise emphasized the need for better information on all these products.

Two studies were therefore commissioned by BETT/EMR over the next few years, the first dealing with caulks and sealants, and the second with weatherstrip products. Their common aims were to catalogue the products, study the existing standards, determine how these standards were being applied and assess their relevance to residential sealing practices. Using these findings, the studies were required to identify the new standards that would be needed. Both studies were conducted by SRC. The findings have been presented in two sets of reports (2, 3).

The study on caulks and sealants confirmed that the existing standards were directed at exterior use on new construction. As such, they failed to cover a number of topics of primary importance in indoor use: the larger range of substrates, the deteriorated conditions of substrates, the finished appearance of an exposed bead, paintability, etc. In

addition, the outgassing of harmful volatiles from caulks and sealants was of little consequence in outdoor use, and had not been studied. The final report (2) recommended a new series of performance standards, a workmanship standard and a procedure for controlling the indoor use of materials containing harmful volatiles.

The study of weatherstrip products revealed hardly any standards relating directly to weatherstrip performance, though some manufacturers were applying their own performance tests. A number of performance tests and specifications were directed at new assemblies (eg. windows or doors) containing weatherstrip products installed under assembly line conditions. These performance tests therefore dealt with the assembly as a whole and did not allow the separation of weatherstrip performance. It was clear that, with one or two exceptions, the existing range of standards constituted a poor basis for quality control, particularly in the context of retrofit applications. The final report (3) therefore recommended an entirely new set of test and product standards for individual weatherstrip products, and a workmanship standard to establish good installation practices.

While these studies were being conducted, EMR's Home Energy Program (HEP) initiated a new project, the purpose of which was to establish a comprehensive knowledge base on retrofit practices by 1988. This knowledge base was seen as having two inter-related components: a series of manuals for the purposes of technology transfer and training, and a series of standards and procedures for controlling the quality of retrofit work and materials.

The work described here is part of this broader initiative, and covers the development of test standards, product standards, workmanship standards and safety procedures related to the indoor use of caulks, sealants and weatherstrip products.

At the outset of this study it was fully recognised that the resulting standards could be viewed only as working drafts. Before they could be enacted as National Standards they would have to be taken through the various formal stages of consensus and approval by the Canadian General Standards Board (CGSB). To expedite this process the study has drawn on the expertise of two Advisory Committees, one dealing with caulks and sealants and the other with weatherstrip products. The membership of the two committees is given under "Acknowledgements", and each committee contained specialists who sat on CGSB's committees on caulks and sealants or weatherstrip products. The strategy has been quite successful; in many instances the committees have helped to redirect the work in accordance with CGSB's requirements.

The findings of the study have been issued in five separate reports, of which this overview is the first in the series. The purpose of this overview is to draw together all the various aspects of the study so as

to give readers a general perspective. The report covers the full set of objectives of the study and then gives an outline of all the work that has been done. A separate section is designed to guide the reader through the four other reports in the series. Finally, the most important results and findings of the study are summarised in a "highlights" section.

2. OBJECTIVES OF THE STUDY

The study was divided into a Stream A, dealing with caulks and sealants, and a Stream B, dealing with weatherstrip products.

In Stream A the general objectives were to develop:

a) A draft Product Standard for caulk and sealant materials,
b) A draft Workmanship Standard covering the indoor use of caulk and sealant materials,
c) A method of quantifying toxic hazards associated with the outgassing of harmful volatiles from caulks and sealants in an indoor environment, and a method of controlling the indoor use of caulks and sealants so as to avoid toxic hazard.

In Stream B the general objectives were to develop:

a) A draft Product Standard for weatherstrip products,
b) A draft Workmanship Standard covering the use of weatherstrip products.

Subsequently it was found convenient to treat the toxicity work as a separate topic. Thus the work could be divided into three parts, with the following specific objectives for each.

2.1 Draft standards for caulks and sealants

The specific objectives, in chronological order, were as follows:

a) Define the important performance parameters of caulks and sealants, and design a series of test methods to measure these parameters.

b) Design, purchase and construct the necessary test equipment.

c) Survey the existing range of caulk and sealant products and select a small number of products (about 20) on which to conduct pilot tests. The selected products had to be reasonably representative of the entire manufactured range.

d) Apply the various tests to each of the short-listed products, assess the findings, revise the test methods as necessary, and propose a system of classifications (eg. pass/fail) based on the measured performance of the products.

e) Set down the test methods in the form of a draft Test Standard.

f) Prepare a draft Product Standard for classifying the performance of products according to the results of the test methods.

g) Prepare a draft Workmanship Standard, covering all the necessary requirements for safety and quality workmanship at site.

2.2 Control of health hazards related to caulk and sealant use

The specific objectives, in logical sequence, were as follows:

a) Conduct a survey of manufacturers and available literature, and determine as far as possible the volatile components of caulks and sealants - either individually or generically. Identify all volatiles with an associated toxicity hazard.

b) Do the same thing for cleaning solvents and primers, as used in the application of caulks and sealants.

c) In consultation with specialists in the field, design test equipment and procedures for identifying volatile emissions and for measuring the rate of emission and its variation with time.

d) Construct the equipment.

e) Conduct tests to identify the volatile emissions from the selected short-listed products (section 2.1 (c) above). Use the findings to design a program of pilot tests for measuring emission rates.

f) Conduct commissioning tests on the outgas equipment (this is the term used to describe the equipment used for measuring rates of volatile emission). Refine the test procedures.

g) Devise a method for deriving the variation of outgas rate with time from the experimental data.

h) Conduct outgas tests on all short-listed products, and determine the variation of outgas rate with time for each important volatile in each product.

i) Conduct a small survey of sealing contractors and determine the amount of caulk and sealant usage in a typical residential sealing job. Also determine the typical duration of a sealing job.

j) Devise a method for combining the results of (h) and (i) so as to calculate the variation of airborne volatile concentration in a house, during and after a sealing operation.

k) Consult with toxicologists and review the relevant literature on modelling of airborne toxic hazards. From this, devise a method for assessing the hazard associated with the airborne volatile concentrations determined in (j).

l) Apply this procedure to the results of all the tested products, and as far as possible assign a safety rating to each.

m) Submit draft Test Standards for volatile identification and outgas testing, and propose a standard procedure for rating the safety of caulks and sealants on the basis of outgas tests.

2.3 Draft standards for weatherstrip products

The specific objectives and chronological sequence are almost identical to those in section 2.1 above.

2.4 Deliverables

Originally it was proposed to submit the results of the study in twelve different reports, but this has now been condensed to four reports in addition to this overview. The reports cover the following parts of the study:

Volume 1. The overview of the study

Volume 2. The draft Test, Product and Workmanship Standards for caulks and sealants, including all developmental work and test results

Volume 3. The results of the survey of hazardous volatiles in caulks, sealants, cleaning solvents and primers

Volume 4. The complete model for applying a safety rating to sealants on the basis of outgas tests, including all developmental work, test procedures, mathematical models and results of the pilot tests

Volume 5. The draft Test, Product and Workmanship Standards for weatherstrip products, including all developmental work and test results

3. GENERAL DESCRIPTION OF THE STUDY

The intention here is to give the reader a general perspective on all the work that has been accomplished, including some of the problems and the way in which these have affected the course of the work. Detailed technical issues are not discussed and technical references are not given - for such information the reader should consult the other reports in this series.

3.1 Defining the limitations of the study

Within a few weeks of starting this study, it was apparent to both HEP and SRC that the series of objectives was open-ended, in that it did not define priorities or the depths to which each aspect should be pursued. A meeting of the two parties was held to discuss these points. It was agreed that the scope of work was considerable and that, to fit within the schedule and budget of the project, some of the work would have to be focussed very narrowly on essentials.

Originally, it was hoped that the study would produce a definitive set of tested and proven standards, but in a more realistic light it was accepted that the study could not resolve all the issues in the several new areas that were to be explored. The underlying objective of the study was therefore changed, and from then on it was viewed as an effort to create a new foundation - one that would serve most of the immediate needs, while providing a useful basis for further development and refinement.

In consequence, many parts of the study have been limited by practical and realistic considerations of time and funding. This is evident throughout most of the reported work on the study.

3.2 Outline of the work history

The study began with the the signing of the contract between HEP and SRC in November 1985. The planned completion date was March 31, 1987.

When the work started, SRC was still engaged on the prior weatherstrip study for BETT (see introduction) and it was felt inappropriate to pursue further weatherstrip work until the findings of this prior study were released. Thus, in this new study, the initial work was focussed on caulks and sealants.

Work on caulks and sealants was conducted in two parallel streams: one directed at the test, product and workmanship standards; the other at toxicity aspects. It was obvious from the outset that the toxicity work would be breaking new ground and would require considerable research and development, as well as involving a great many diverse elements that had to be drawn together. Therefore, this stream was assigned the higher priority.

The first work consisted of the review of toxic volatiles in caulks and sealants, and the survey of sealing contractors. These were brought to substantial completion within three months, and the two sets of findings were issued in a single draft report. A continuing low level effort was then maintained to update this report and insert new material on cleaning solvents and primers.

Meanwhile, several experts had been consulted on test equipment design and test procedures, for both product performance testing and outgas measurements. The most suitable approaches began to take shape during the first months of 1986. By May, work had started on volatile identification tests, the outgas test equipment was designed and in the process of construction, and the manufacture and purchase of equipment for performance testing was proceeding on a broad front.

A large number of commissioning tests and preliminary experiments was conducted on the outgas equipment during the summer of 1986, together with other developmental performance tests. Towards the end of these tests, work was started on the development of a mathematical model for analysing the test results, and in the test laboratory the outgas testing was halted and attention was focussed on the performance testing of caulks and sealants.

The mathematical model started to take on its final form in November 1986, and the requirements of the model led to changes in the test procedures. From this point onwards, equal priority was given to the final series of outgas tests and performance tests.

Around this same time, SRC completed its work on the prior weatherstrip study. The findings were issued, together with a proposed schedule for attaining the weatherstrip objectives of the current study. Work started in January 1987 on the design and acquisition of weatherstrip test equipment.

By February 1987 it had already become clear that the study would fail to meet the scheduled completion date of March 31, 1987. A realistic revised schedule was therefore prepared by SRC, with a proposed completion date of July 31, 1987. HEP approved the requested extension of termination date, and asked SRC to make arrangements to present its up-to-date findings to the two Advisory Committees on May 6 and 7.

By March 1987 all outgas tests were complete, and a draft report on the safety rating of caulks and sealants had been circulated and reviewed. The performance tests on caulks and sealants had been taken as far as practicable, and considerable progress had been made in preparing all the required draft standards. However, the initial air leakage tests on weatherstrip products had encountered a number of developmental problems, and some of the findings suggested that a completely new approach would be required in the testing and classification of weatherstrip products.

In preparation for the committee meetings in May, an attempt was made to complete the outgas report, but this ran into problems in the form of two major types of anomaly in the test data, requiring a major change in the mathematical model and a total re-write of the report. This was not completed in time for the meetings, though the issues were presented and discussed. The test methods and test results on caulk and sealant performance were presented, and preliminary outlines of the workmanship standard and product standard were submitted. The response of the committee was generally approbative; some improvements were suggested, and it was recommended that two of the proposed test methods be eliminated.

At the meeting of the weatherstrip Advisory Committee there was little information to present, most of the findings up to that time had been inconclusive or subject to developmental problems. A new approach to weatherstrip performance testing was presented, based on the useful operating range (or deflection range) of the weatherstrip seal. It was pointed out that, when this concept was applied, some high quality products would fail to qualify, while some of the more simple and inexpensive products would achieve high classifications. The critical information still had to be gathered, and the Committee was not able to give a definitive decision at that stage. The proposed remaining schedule of tests was submitted and approved.

Over the next few weeks priority was given to the completion of all reports on caulks and sealants. At the same time, the weatherstrip tests continued to present problems. At one point it seemed impossible to develop a useful and reliable air leakage test method with the required degrees of accuracy and repeatability. The test equipment was scrapped and an entirely new test jig was developed and built. This jig was found to be satisfactory and a large series of tests was conducted, involving six tests on each of 24 products. By this time it had become clear that this test was still of major importance, and therefore the test series was given priority at the expense of other tests. The justification for neglecting the other tests is twofold: first, because of unforeseeable difficulties, it was impossible to cover the required vast range of work within the schedule of the project - even within the extended schedule; secondly, most of the undeveloped tests are simple adaptations of existing standard test methods.

By the end of July - the new deadline date - the tests were still not complete. In SRC's view it was clear that the value of the final report would be considerably diminished if the main series of tests could not be brought to a successful conclusion. Also, it was felt that the findings might evoke some considerable resistance from the weatherstrip manufacturing industry, leading to rejection of the rather radical method of performance classification. It was therefore considered important to spend some considerable time in developing the method, so as to establish its credibility. Work was intensified and was then stopped in September, at which point the major effort was switched to analysis and preparation of the final report.

At the time of writing, all reports, including this overview, will be submitted to HEP by December 21, 1987, and plans have already been made to hold a final meeting of the two Advisory Committees on January 13, 1988, to review all the deliverables. The findings from these meetings are in the future and therefore have not been included.

In summary, the study has substantially achieved its various objectives. The deliverables on caulks and sealants are close to what was required, and in some cases go considerably beyond this. The deliverables on weatherstrip standards are also fairly close to what was required. The test methods comprise a complete set, though only a few of them - the most difficult and innovative ones - have actually been subjected to complete pilot tests. The failure to meet the project deadline is regrettable. It is attributable not to poor scheduling or inadequate manpower resources, but to the large number of developmental problems that were not foreseeable at the outset.

4. GUIDE TO THE TECHNICAL REPORTS

All four technical volumes are written as stand-alone reports, including introductory material which explains how each report fits into the overall scheme of the study.

Volume 2

This volume is entitled "Draft Standards for Sealing Workmanship and Caulk & Sealant Performance."

The report describes the selection of a representative range of products for the pilot tests, then discusses the background and details of 17 proposed Test Methods. Each test method is discussed in terms of the intention of the tests, the results of the pilot tests, the assessment of the value of the usefulness of the test and the recommendations concerning the final test method. Three appendices consist of drafts of the proposed Test Standard, Product Standard and Workmanship Standard, and a fourth appendix presents the results of the pilot tests.

Volume 3

This volume is entitled "A Survey of Toxic Volatiles in Caulks, Sealants, Cleaning Solvents and Primers Used in Air Sealing Practice".

Part 1 of the report is taken up with a summary of toxic volatiles in caulks and sealants. Much of this information could not be got from manufacturers and is therefore based on published research and studies. The findings are presented under individual headings for each of the 26 identified generic types of caulk or sealant. Typical formulations are presented, and this is followed by a hazard assessment of the various components.

Part 2 gathers together the findings from Part 1, and attempts to identify those toxic volatiles which should be given preferential study in the planned outgas tests.

Part 3 presents a brief hazard assessment of toxic volatiles in cleaning solvents and primers.

Volume 4

This volume is entitled "The Safety Categorization of Sealants According to Their Volatile Emissions".

Part 1 covers the development of test equipment and test procedures for identifying the volatile emissions from caulks and sealants, and for measuring the variation of outgas rate with time. A large section is devoted to preliminary experiments, which were designed to reduce experimental error, improve the experimental repeatability and define the test sequence most suitable for mathematical analysis of results. The refined test procedures have been set down as draft Test Standards in Appendix A.

Part 2 covers the development of a mathematical model which describes the movement of volatiles through the body of a caulk or sealant bead. This model was a necessary component in the analysis of test results.

Part 3 covers the application of this mathematical model to actual test results, and discusses the problems encountered. From this, a simplified or crude method of analysis is proposed for routine testing.

Part 4 covers the modelling of house conditions. In this, the objective is to calculate how the airborne volatile concentration will vary in a house during the sealing work and for some time afterwards. The mathematical model assumes a standard house configuration, with safety factors to accommodate variations in house design. The assumed sealant usage pattern, in terms of the amount used and the periods over which it is applied, are based on the findings of the survey of sealing contractors - as presented in Appendix B.

Part 5 moves from building science into the area of toxicology. The deficiencies of toxicological databases are discussed, and a system is proposed for working around these limitations so as to give a method of rating the sealant. The mathematical equations of this method are then developed.

Part 6 gives a detailed description of the computer program that has been developed and is listed in Appendix C. The input to this program consists of outgas test data, and the output consists of a safety rating of the tested sealant, which is determined by applying all the various stages of mathematical modelling developed earlier. When applied to the results of all the pilot tests (as given in Appendix D), it is shown that a definitive rating cannot always be applied. The reasons are discussed and modifications to the outgas test method are proposed (these modifications are included in the draft test method).

The report ends with an extensive discussion of the main conclusions and the recommendations arising from them.

Volume 5

This volume is entitled " The Development of a Draft Test Standard, Product Standard and Workmanship Standard for Weatherstrip Products and Their Residential Applications."

The report presents the accomplished work in chronological sequence, with an emphasis on the experimental and developmental problems that dominated this part of the study.

The main text starts with a description of the representative range of products selected for the pilot tests, then goes on to describe the abortive first series of airtightness tests. These tests led to the establishment of an important new concept in weatherstrip performance, namely the **deflection range**. The importance and implications of this are discussed.

Three test methods were needed to establish the deflection range, and the majority of the report is devoted to the development of these methods and the results of pilot tests.

Sixteen test methods and procedures are presented and discussed. Nine of these are based on the developmental work and operating experiences, and one is a simple test based on SRC's experiences with site installations of weatherstrip products. The remaining six test methods are considered to be important components of the overall scheme of tests, but there was no time to conduct developmental work. These remaining tests are based on existing and proven test methods and require little modification.

The draft Test Standard, Product Standard and Workmanship Standard are presented in three appendices. The results of the pilot tests are presented in a fourth appendix.

5. MAIN FINDINGS AND HIGHLIGHTS

For caulks and sealants the proposed Test, Product and Workmanship Standards are fairly uncontroversial. The performance specifications are not unduly stringent when applied to a representative range of products. Three of the proposed test methods can probably be discarded as being irrelevant, or as already having served their purpose. The greatest remaining issue concerns the Hockman Test Procedure, which may have difficulty in securing CGSB approval in its proposed form.

The proposed Test Standard and Product Standard for weatherstrip products involve radical new concepts which may meet with some resistance. The first of these is the **deflection range** parameter. All products require some degree of compression or deflection before they achieve an acceptable level of airtightness. Then, if the compression or deflection is increased, a point will be reached where the required operating force is too large for normal applications. The deflection range is the range of movement within these two limits. Many of the tested products have been found to have a deflection range too small for practical purposes, making them generally unsuitable as weatherstrip products. The deflection range is believed to be a valid and realistic parameter, and the fact that it leads to a "fail" classification of a large proportion of products is, perhaps, a comment on the products currently available.

Most weatherstrip seals will deform or shrink when aged, depending on the way in which the seal is mounted or restrained. Where shrinkage occurs, and the seal pulls away from the end of the installation, a large air leakage opening is usually created. Thus, an aged product gives a realistic indication of what happens in an actual installation, and it is realistic to measure the air tightness of aged products with seals that have shrunk away from the ends of the test sample. This has the effect of reducing the deflection range even further, leading to a "fail" classification of more products.

Once the deflection range is accepted as a valid concept, then it is easy to see the weaknesses in current methods of weatherstrip installation. When a product is installed, the installer has virtually no indication of whether it is sealing satisfactorily, whether the closing force requirement is too high, or whether the seal will be able to accommodate warpage or other forms of structural movement. If the deflection range is specified for a product, then the installer will know how to set up the product initially. This factor has been taken into account in the Workmanship Standard, and effectively promotes weatherstrip installation practices from an imperfect art into an exact skill.

In developing test methods for weatherstrip products, one of the greatest difficulties centres on the large variability in design and operation. This gives rise to a range of different ways of mounting and testing the products. Separate test procedures have been specified to cover the various ways of mounting, testing and presenting the most important dimensional parameters.

Tests have shown that all seals display two regimes of air leakage, termed **convective** and **molecular**. In the convective regime a very small change in deflection or gap (of the order of 0.1 mm or 0.004") can cause the air leakage rate to change by typically a factor of two. An existing National Standard for windows specifies air leakage rates that fall in this same regime, and it is argued that, in practice, a coat of paint could change these rates considerably. Furthermore, any slight structural changes could cause large changes in air leakage. Thus, tested air leakage performance is generally not a good indicator of real-life performance.

It is argued that, **ideally**, weatherstrip seals should be required to operate in the molecular regime. This regime has very low rates of air leakage, and these rates are relatively unaffected by changes in deflection or gap. However, if this requirement were applied to the current range of manufactured products it is likely that more than 99% would fail, since the required compressive force would be far too high. This kind of performance is not unattainable, since one of the tested products has been shown to work satisfactorily in the molecular regime, but it is perhaps premature to require a similar performance of all products at the present time.

The outgas test equipment and test procedures, developed during the course of this study, are believed to be satisfactory and suitable for future applications. However, the test results will not permit a safety rating of the sealant unless all the volatile components, and their outgas rates, are measured. This includes water vapour, which may have a critical effect on the important mass balance checks in the data analysis. As a consequence, all the volatile components must be picked out and quantified in the chemical analysis procedures, and this will add considerably to the cost of this analysis.

A model has been developed to describe the loss of volatiles from a sealant, and to facilitate the analysis of outgas test data. This has been termed a **reservoir model**, since it assumes that the sealant consists of a porous matrix containing a falling reservoir of liquid volatiles. The model gives a good account of the observed phenomena. In some instances, where the outgas data show an orderly variation with time, the model can be used to derive the values of a number of fundamental parameters.

Most products show an erratic variation of outgas rate with time over the first four hours of outgassing. Many of these erratic variations follow a common pattern. The proposed explanation is that the sealant develops a skin which prevents volatile emission, then the volatile vapour pressure builds up behind the skin until it is high enough to rupture the skin, causing a fast release of volatiles.

To assign a safety rating to a sealant it is necessary to combine building science and toxicology. Building science defines the pattern of airborne concentration variations that occur in a house when a particular sealant is used in prescribed quantities. Toxicology determines whether this pattern is likely to be hazardous to the house occupants or the sealing workers. To conduct this hazard assessment it has been necessary to develop a mathematical model of body response and a set of criteria for evaluating this response. This introduces a number of toxicological parameters and is useful in identifying the type of information needed in the model. This toxicological information, which is essential to the proper operation of this model, has been been found generally inadequate, with many serious gaps. In many cases the lack of toxicological data has prevented the assignment of a safety rating to the tested sealants. If the proposed method of sealant safety rating is to be taken onward, refined and applied to outgassing from other types of product, then it will be essential to develop and improve the toxicological databases on which the method depends.

6. REFERENCES

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